Wave overtopping on steep low-crested structures: another climate change challenge

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Climate change is responsible for sea level rise and increase in the storminess (i.e. more frequent and more severe storms), posing risks to coastal communities. Floods on the coastline are expected to increase, leading to potential human life losses and significant economic damage. In this climate change scenario, the existing coastal structures protecting the Belgian coastline against wave attack should remain at least equally effective against future storms. Therefore, good knowledge of the coastal processes is required to correctly assess the safety of the existing coastal structures in this new scenario and to improve design guidelines. The main coastal processes involved are, among others, wave overtopping over the crest of the structures, wave run-up on sea dikes and wave forces and pressures exerted by the waves attacking the structures.

Wave overtopping is a key design parameter as it determines the necessary crest level of coastal structures (e.g. breakwaters) that limits the amount of water passing over the structure during wave attack. Traditional research has focused on analysing the average wave overtopping rate establishing its relation with diverse wave parameters of the sea state (wave height, wave period, wave steepness, etc.) and structural parameters (slope angle, crest freeboard, etc.). Furthermore, physical insights show that the damage on infrastructures and people near the coast during a storm is also related to individual volumes from single wave overtopping events.

Despite the large scientific literature available, there are still knowledge gaps to be covered in order to improve the understanding of wave overtopping under different conditions. This knowledge gap consists of overtopping data for steep low-crested structures (coastal structures with steep slopes and vertical walls, with a crest freeboard ranging from small to zero). This type of coastal structures with small freeboards are relevant in a climate change scenario where the sea level is increasing while the crest level of the existing structures is impossible or very expensive to modify. Improving the knowledge on various processes related to wave overtopping will eventually lead to more accurate overtopping prediction formulae with larger ranges of application, and hence to safer coastal defence structures under a climate change scenario.

The EurOtop (2007) manual is the reference manual in Europe about wave overtopping and overtopping assessment of coastal structures. It contains several overtopping prediction formulae for various types of coastal structures, lacking however prediction formulae valid for steep low-crested structures. An updated version, EurOtop (2016), is available with improved overtopping prediction formulae.

To extend the wave overtopping data available in the scientific literature, we performed 2D physical model tests at the large wave flume of Ghent University (Belgium). The experiments consisted in overtopping tests on smooth impermeable coastal structures, both with deep and shallow water conditions. The tests were focused on obtaining average and individual wave overtopping data for a range of slope angles α from steep to vertical walls and for a range of relative crest freeboards R_c/H_{m0} (where R_c is the crest freeboard of the structure and H_{m0} is the significant wave height) from large to zero. Four different datasets resulted from these physical model tests: dataset 'UG10', 'UG13', 'UG14' and 'UG15', all of them focusing on steep low-crested structures.

These new datasets obtained at Ghent University are useful to improve the accuracy of the existing prediction formulae on the range of steep low-crested structures. Recently, van der Meer & Bruce (2014) presented a new overtopping prediction formula fitted through the UG10 dataset and thus being in the range of application of steep low-crested structures. However, this formula underpredicts the results of the UG13, UG14 and UG15 datasets for very steep slopes and vertical walls, and for the zero freeboard limit case. By using the new Ghent University overtopping datasets, improvements on the accuracy of the prediction formulae can be made.

Keywords: coastal engineering; climate change; coastal structures; wave overtopping; steep low-crested structures; physical modelling

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PREFACE

This is the 'Book of Abstracts' of the 17th edition of the VLIZ Marine Science Day, a one day event that was organised on 3 March, 2017 in VIVES, Brugge.

This annual event has become more and more successful over the years. With more than 400 participants and more than 100 scientific contributions, it is fair to say that it is the place to be for Flemish marine researchers and for the end-users of their research. It is an important networking opportunity, where scientists can meet and interact with their peers, learn from each other, build their personal professional network and establish links for collaborative and interdisciplinary research.

Marine scientists from all Flemish universities and scientific institutes – and representing all marine science disciplines – have contributed to this volume. The book thus illustrates the diversity, quality and relevance of the marine sciences in Flanders (and Belgium): it provides a beautiful and comprehensive snapshot of the state-of-the-art of marine scientific research in Flanders.

Pre-doc and post-doc scientists present their research in an exciting way and communicate their fascinating science – and its importance to society – to the wider public. We thus hope to demonstrate the excellence of Flemish marine science and to increase its national and international visibility.

The volume of research that is presented here holds a great promise for the future. It shows that marine science is a very lively discipline in Flanders, and that a new generation stands ready to address the grand challenges and opportunities that our seas and oceans represent.

New this year are the Brilliant Marine Research Ideas, an initiative sponsored through the philanthropy scheme of VLIZ. We are proud to announce that an initial batch of 4 ideas will be sponsored. We'll hear about the results in the next edition of the Marine Science Day.

I want to congratulate all participants with their contributions, and I invite them all to become members of VLIZ and to actively participate in our events and activities in the future.

Bruges, 3 March 2017
Prof. Dr Jan Mees
General Director VLIZ

TABLE OF CONTENTS

VLIZ Master Thesis Awards

VLIZ North Sea Award

Oral, Demo and Poster Presentations

Development of diffusive gradients in thin films (DGT) passive samplers for simultaneous measurement of Platinum, Palladium, Rhodium and Mercury in surface water

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Increasing anthropogenic activity often has detrimental effects on human health and the environment due to the accompanying emissions of toxic compounds. The increased application of Platinum Group Elements (PGEs) (Pt, Pd, Rh, Ru, Os and Ir) in the last decades, especially as car catalysts but also in other applications, makes it necessary to monitor the concentration of these elements in the environment, investigate their environmental transformations and bioavailability. Mercury (Hg) is also recognized as one of the most toxic trace elements, whose natural cycle has been altered by anthropogenic activities. Complex biogeotransformations result in different chemical species, with varying toxicities and mobility, which need close monitoring. The concentration of these elements usually extremely low in the aquatic environment, which makes the analysis challenging.

As the toxicity, bioavailability and the cycle of environmental contaminants can strongly be influenced by their chemical speciation, in recent years, the importance of speciation analysis has been recognized by the environmental monitoring and assessment community, leading to the development of an increasing number of speciation techniques. The in situ passive sampling technique diffusive gradients in thin films (DGT) as a speciation tool is based on the binding of labile metal species on a resin gel layer via the diffusion through a diffusive hydrogel (agarose or polyacrylamide) using Fick's Law. The concentration gradient built between the bulk solution and the resin gel makes pre-concentration of solutes possible. Using Fick's law, the time-weighted average concentrations of labile metal species can be obtained in situ. This technique has been widely used to assess trace elements such as Cd, Cu, Ni, Pb, Co, Zn in aquatic systems, but never been applied to test PGE elements until now.

The aim of this study was to develop the DGT technique for the assessment of PGE and Hg using two novel resins R14 and R20, which were designed specifically for above elements. This implies that the binding of the PGEs to the resin is strong, irreversible, almost instantaneous and the accumulated metals amounts are well below the capacity of the resin. The method development involves several different steps: 1) selection of an appropriate diffusive gel 2) the selection of an appropriate resin or binding phase for the PGEs and Hg, 3) development of an efficient elution method for the PGEs and Hg from the resin gel, 4) evaluation of the linear response in function of the deployment time, 5) determination of diffusion coefficients for the PGEs and Hg in the diffusive gel, 6) study the selectivity of the tested resins gels, 7) the accumulated metal amount is well below the capacity of the binding gel, 8) fast kinetics of the resins gels.

Agarose diffusive gel (AGA) (1.5% agarose) was chosen for lower interaction with PGEs and Hg, adequate blank values and linear response (R2 = 0.99) in function of the time were obtained for the new resins gels and diffusion coefficients could be determined. An aqua regia and thiourea in hydrogen chloride elution methods gave a recovery for PGEs and Hg over 90% and 80% for the R20 and R14 resins gels, respectively. The selectivity test showed these two resins have higher selectivity to PGE and Hg than other trace elements even though they are at very high concentration level and the analysis of PGEs and Hg by sector field ICP-MS optimized. The new resin gels showed capability of accumulation concentration of PGEs and Hg of each hundred times higher than their reported concentrations in the aquatic environments.

Preliminary deployments in the Zenne River and UZ hospital effluent, Brussels, Belgium, showed that Pt, Pd, Rh and Hg can be quantified by the DGT technique using both evaluated resins in fresh water.

Keywords: DGT; PGEs; Hg; SF ICP-MS; diffusive coefficient; surface water; speciation